Comment about pion electro-production and the axial form factors

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The claim by Haberzettl [1] that the axial form factor of the nucleon cannot be accessed through threshold pion electroproduction is unfounded.

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The soft pion theorem [2] for pion electro-production off a nucleon has the form:

$$f_\pi M(\gamma^* + N \to \pi(q_\mu = 0) + N) = -i \lim_{q \to 0} \left(q_\mu \langle N| \int d^4x e^{iq.x} T(A^\mu(x), \varepsilon.J(0))|N\rangle \right) - \langle N\left|[Q_5, J.\varepsilon]\right| N\rangle . \qquad (1)$$

The commutator $[Q_5, J.\varepsilon]$ is given by current algebra and is equal to the axial current. So, up to corrections of order m_π, this reaction gives access to the axial form factors [3] of the nucleon. One can also derive (1) " la Adler" using PCAC in the presence of an electro-magnetic field.

The first term on the RHS of (1) is the amplitude $T_{A\gamma}$ for producing an axial current A^μ by the electro-magnetic interaction $\varepsilon.J(0)$. The crucial point is that, because of the factor q_μ, only the part of $T_{A\gamma}$ which is singular at $q_\mu = 0$ can contribute in the limit $q_\mu \to 0$. This implies that the only diagrams which survive are those where the axial current is attached to an *external* leg, and in the present case the only external legs are those of the nucleon. Therefore in Fig.3 of Ref. [1] only the first two diagrams have to be kept because *the sum of the others vanishes when one contracts with q_μ and takes the soft pion limit.*

The confusing point in Ref. [1] is that the author has split the axial current in what he calls a "weak" part $J_{A,W}$ and a "hadronic" part $J_{A,H}$, so that only $g_A(t)$ appears in the "weak" part. The price to pay for this strange splitting is the presence of an unphysical pole at $t = 0$ in both $J_{A,W}$ and $J_{A,H}$. Of course these poles cancel out in the full current. The trap in the reasoning of Ref. [1] is that the contributions of $J_{A,W}$ and $J_{A,H}$ to $T_{A\gamma}$ are calculated separately. Due to the unphysical pole the author finds a finite contribution due to $J_{A,H}$ but he leaves the contribution due to $J_{A,W}$ unspecified, arguing that it cannot be computed explicitly due to the nucleon structure and that all what matters is that it depends only on $g_A(t)$. This is the basis for his argument and it is of course completely misleading since we do know that the pole part of $J_{A,W}$ must cancel exactly the one of $J_{A,H}$, and the rest vanishes in the soft pion limit. In others words the quantity called $\mathcal{W}$ by the author is actually zero in the soft pion limit, independently of the nucleon structure. This is enough to invalidate the conclusions of Ref. [1].

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[1] H. Haberzettl, Phys.Rev.Lett.**85** (2000) 3576.
[2] For example: S.L. Adler and R.F. Dashen,*Current algebras and applications to particle physics* (W.A. Benjamin, New York, 1968).
[3] Under favourable kinematical circonstances, threshold pion electro-production gives access not only to the axial form factor, $g_A(t)$, but also to the pseudo-scalar one, $g_P(t)$, as shown in: S. Choi *et al.*, Phys.Rev.Lett.**71**, 3927 (1993).

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